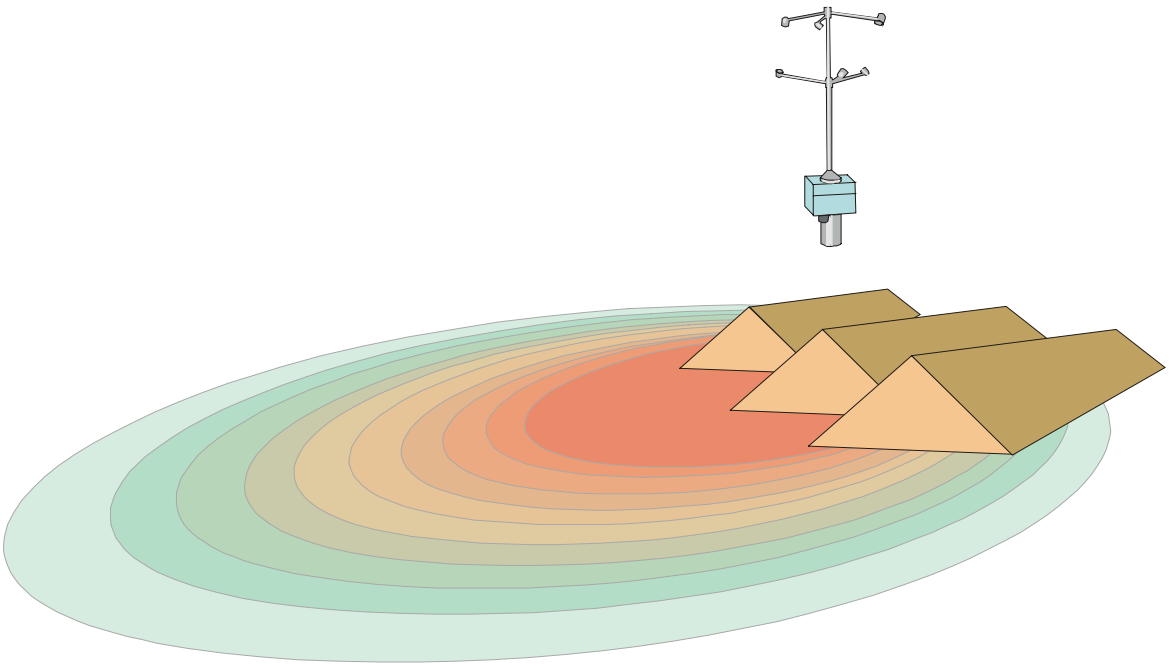
OdorSonic

Meteorological Measurement System
Odour Online Dispersion Simulation

Windows 2000 / XP

User's Manual



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PART I User Interface

I - 1 General Notes

The present documentation refers to a functional non limited version of the measurement and simulation program OdorSonic. The program code has been developed during several years and has been tested thoroughly. However, especially using unconventional computer configurations program errors may occur. We do not accept any liability for those errors.

The copyright of the program system *OdorSonic* and the corresponding user's manual belongs exclusively to the:

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Reference

OdorSonic is drafted as single place license. Using *OdorSonic* on a network may result in error messages. The removal of those errors and an adaptation of the system to the network can only be granted in the scope of a maintenance contract.

Hardware Requirements

Basically, *OdorSonic* is able to run on every PC using Windows as operating system. For reasons of operating safety, however, Windows 2000 or Windows XP should be applied. Commonly, computers for measurement purposes have to satisfy particularly high quality and safety requirements. Therefore the program system *OdorSonic* should be installed on a well tested computer consisting of high value components.

Technical minimum requirements of hardware parts:

- Pentium III or higher
- ≥ 256 MByte RAM
- ≥ 100 MByte free hard disk space
- CD ROM drive
- At least one buffered „quick" COM-RS232 PC port
- Graphic Card: 16 MByte
  Resolution: ≥ 1024 x 768 Pixel
  Colour palette: ≥ High Colour (16 Bit)

I - 2 Program Set-Up

- Insert the OdorSonic-CD to the CD drive of the computer

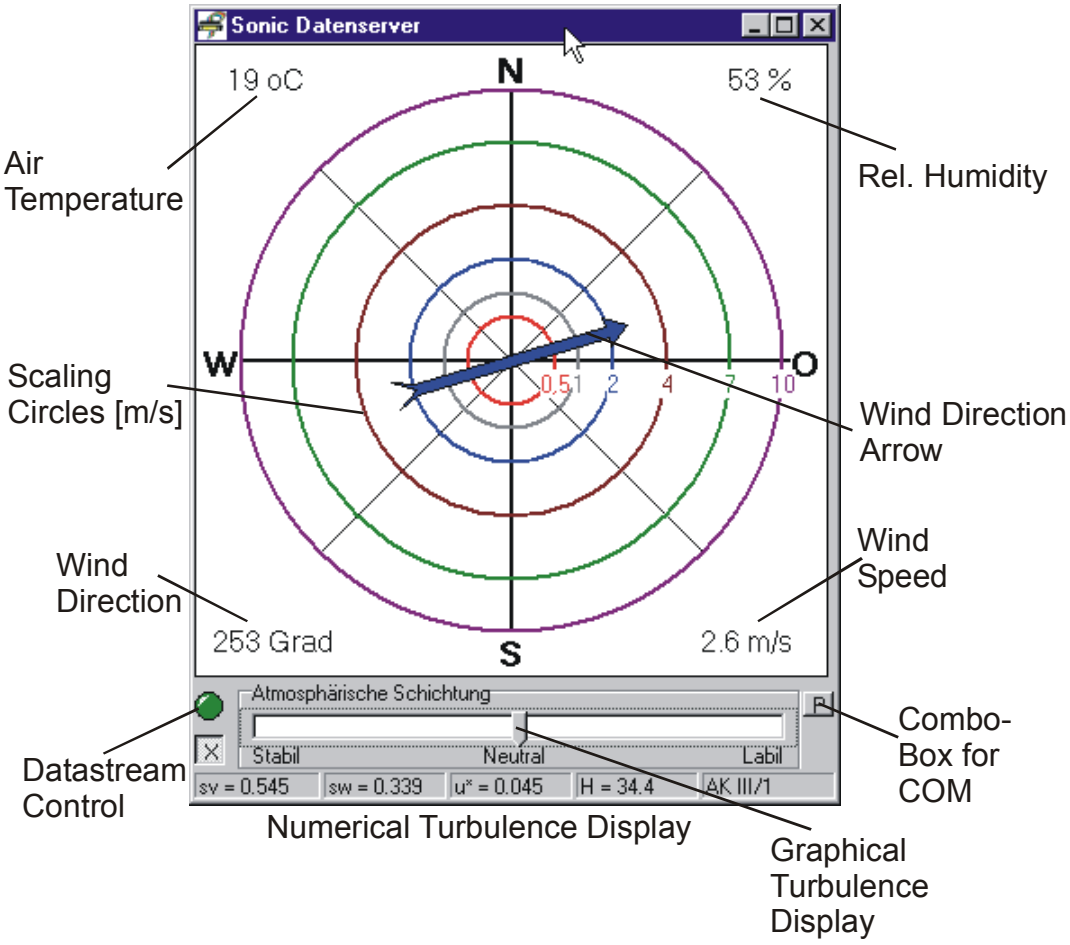
- Choose the set-up program in the directory, disk 1 on the CD and start it with a double click
- The subsequent interactive installation of the OdorSonic package will be self-explaining following to the standards of conventional windows programs. The program will set up all directories and components on the computer necessary for correct operation: interface program (SonicDataServer), database, program for dispersion simulation (OdorSonic), project data set, entries to the windows registry etc.

I - 3 Introduction to the Software OdorSonic

After starting the computer the *SonicDatenServer* with the following program icon

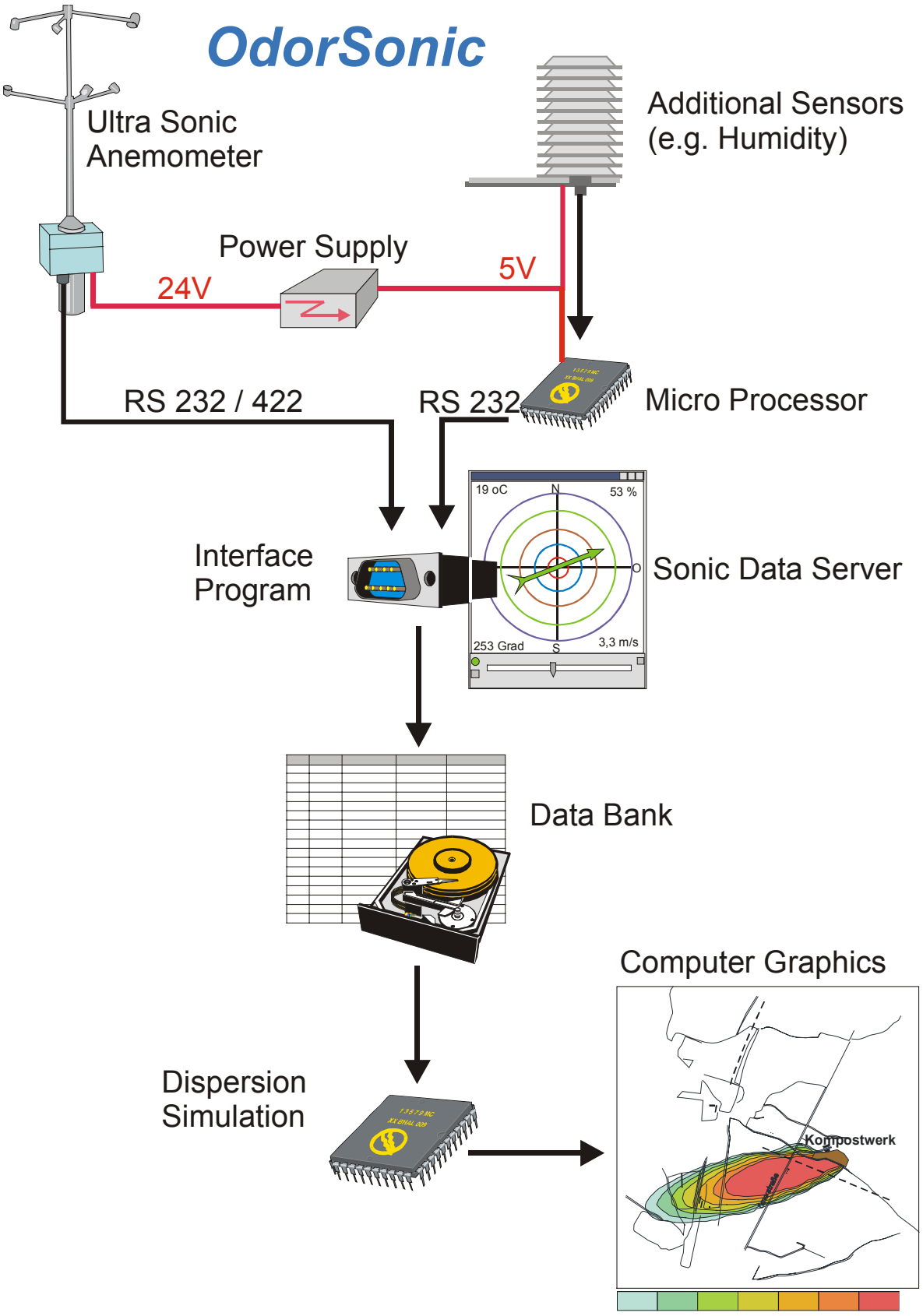
it appears automatically if there is an entry in the AutoStart group; the program symbol will be displayed in the task bar. The application *SonicDatenServer* runs permantely in order to read the meteorological measurement data and to save them in the database.

If the program SonicDatenServer is terminated no meteorological measurement data can be registered!



With standard settings of the SonicDatenServer all 3 wind speed components u, v and w are registered with 10 Hz. Subsequent, wind direction and wind speed are averaged of 10 minutes. This average time corresponds to a source distance of about 1,5 km assuming moderate transport velocities of the odorants. Further more, turbulence data which are important for the dispersion simulation of pollutants and odorants in the atmosphere are sampled and saved as standard deviations of the components u, v and w. These are much more precise measures in comparison with the usual diffusion categories used so far by common dispersion calculations.

The program SonicDatenServer is constructed as OLE server (Object Linking and Embedding), supplying the database and the dispersion program with statistical processed meteorological data. One of the advantages of OLE and COM objects is a well defined Windows interface so other applications may have direct access to the data. This way many extern programs like MICROSOFT WORD or EXCEL for example can read the wind data online and may be used to process them.

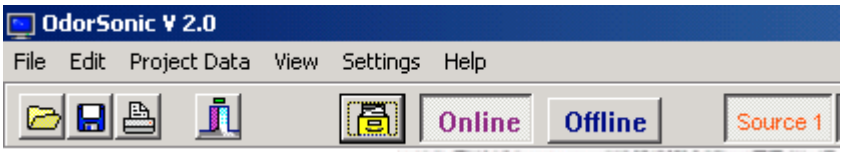


Setu up scheme of the OdorSonic system

The program OdorSonic is launched by a double click on the monitor symbol :

The maximised main window of OdorSonic, can be shut through a click on the button in the right corner on the top of the window. Clicking on the button will minimised the window, whereas a click on the button shuts the window and displays it as a little program symbol in the task bar.

After starting the program the OdorSonic window comes up with the title bar on the top, underneath it follows the menu bar and the tool bar:



I - 3.1 The File Menu

The menu File consists of the subsequent functions:

- *Open*
- *Save*
- *Save as ...*
- *Print ...*
- *Printer Settings*
- *Exit*

The menu entries *Open, Save* and *Save as ...* refers to the project data set. Clicking on the *Print* entry the content of the client window as well as respective information and data are printed on a connected printer. *Printer Settings* provides a dialog for the configuration of the printer; clicking on *Exit* will terminate the program and shut the window.

The same functions may also be activated by clicking on the respective speed buttons:

Open

Save

Print

Exit

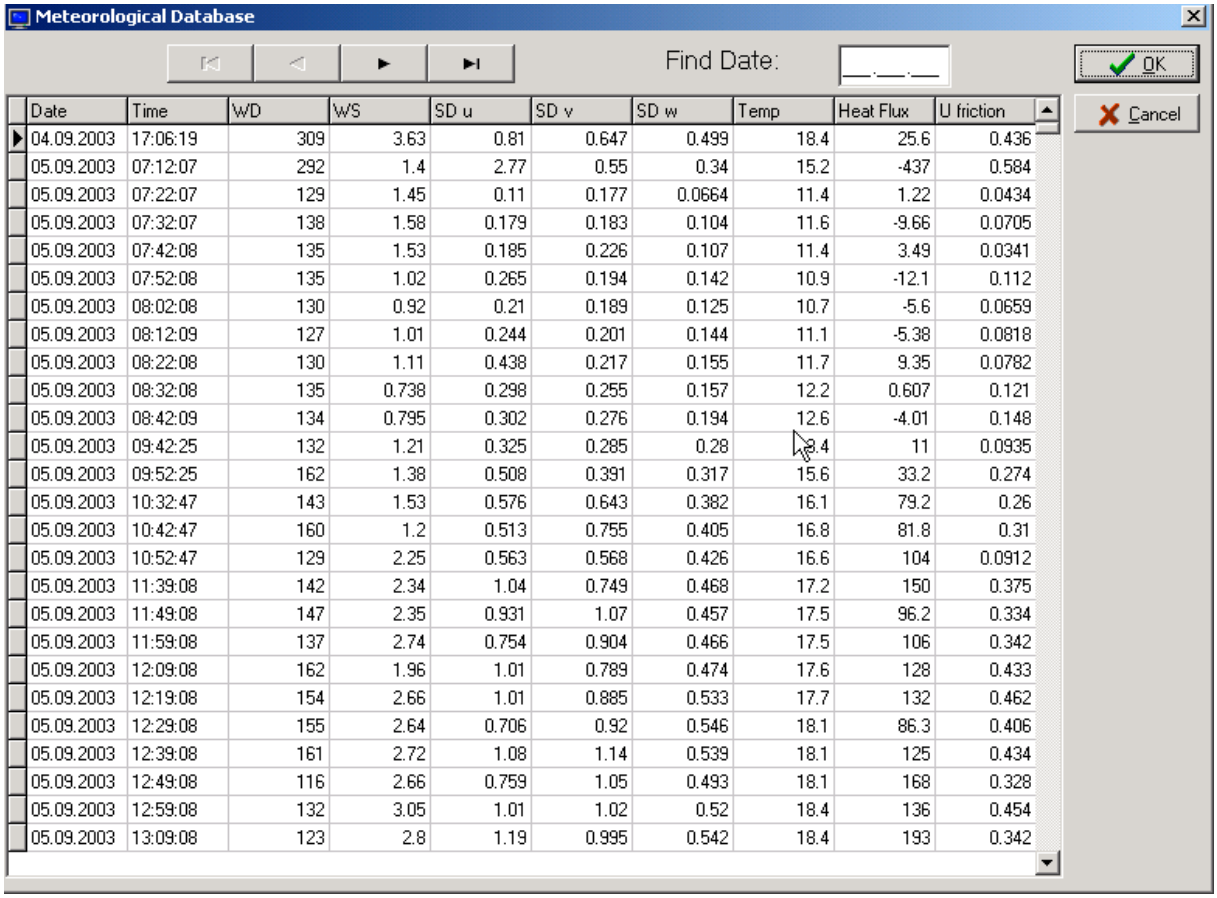
I - 3.2 The Edit Menu

The Edit Menu contains the following entries:

- *Start Simulation*
- *Database*
- *Save graphic as jpg*
- *Copy*

Clicking on Start Simulation launches a dispersion simulation. This function is mainly used in the Offline modus of OdorSonic after typing in some meteorological data. In the Online modus a dispersion simulation is automatically performed every 10 minutes and the calculation results are displayed on the screen.

The *database* can also be opened by clicking on the button.



Date	Time	WD	WS	SD u	SD v	SD w	Temp	Heat Flux	U friction
04.09.2003	17:06:19	309	3.63	0.81	0.647	0.499	18.4	25.6	0.436
05.09.2003	07:12:07	292	1.4	2.77	0.55	0.34	15.2	-437	0.584
05.09.2003	07:22:07	129	1.45	0.11	0.177	0.0664	11.4	1.22	0.0434
05.09.2003	07:32:07	138	1.58	0.179	0.183	0.104	11.6	-9.66	0.0705
05.09.2003	07:42:08	135	1.53	0.185	0.226	0.107	11.4	3.49	0.0341
05.09.2003	07:52:08	135	1.02	0.265	0.194	0.142	10.9	-12.1	0.112
05.09.2003	08:02:08	130	0.92	0.21	0.189	0.125	10.7	-5.6	0.0659
05.09.2003	08:12:09	127	1.01	0.244	0.201	0.144	11.1	-5.38	0.0818
05.09.2003	08:22:08	130	1.11	0.438	0.217	0.155	11.7	9.35	0.0782
05.09.2003	08:32:08	135	0.738	0.298	0.255	0.157	12.2	0.607	0.121
05.09.2003	08:42:09	134	0.795	0.302	0.276	0.194	12.6	-4.01	0.148
05.09.2003	09:42:25	132	1.21	0.325	0.285	0.28	13.4	11	0.0935
05.09.2003	09:52:25	162	1.38	0.508	0.391	0.317	15.6	33.2	0.274
05.09.2003	10:32:47	143	1.53	0.576	0.643	0.382	16.1	79.2	0.26
05.09.2003	10:42:47	160	1.2	0.513	0.755	0.405	16.8	81.8	0.31
05.09.2003	10:52:47	129	2.25	0.563	0.568	0.426	16.6	104	0.0912
05.09.2003	11:39:08	142	2.34	1.04	0.749	0.468	17.2	150	0.375
05.09.2003	11:49:08	147	2.35	0.931	1.07	0.457	17.5	96.2	0.334
05.09.2003	11:59:08	137	2.74	0.754	0.904	0.466	17.5	106	0.342
05.09.2003	12:09:08	162	1.96	1.01	0.789	0.474	17.6	128	0.433
05.09.2003	12:19:08	154	2.66	1.01	0.885	0.533	17.7	132	0.462
05.09.2003	12:29:08	155	2.64	0.706	0.92	0.546	18.1	86.3	0.406
05.09.2003	12:39:08	161	2.72	1.08	1.14	0.539	18.1	125	0.434
05.09.2003	12:49:08	116	2.66	0.759	1.05	0.493	18.1	168	0.328
05.09.2003	12:59:08	132	3.05	1.01	1.02	0.52	18.4	136	0.454
05.09.2003	13:09:08	123	2.8	1.19	0.995	0.542	18.4	193	0.342

The database is build as a table and saves the meteorological data in the following columns:

- Date
- Time
- WD : wind direction in degrees
- WS : wind speed in m/s
- SD u (standard deviation of the wind component u) in m/s
- SD v (standard deviation of the wind component v) in m/s
- SD w (standard deviation of the wind component w) in m/s
- Temp : air temperature in ^{0}C
- Humidity : relative humidity in % ⊗
- Precipitation : precipitation in mm ⊗
- Heat Flux : vertical heat flux in W/m^2
- U friction : friction velocity in m/s

Inserting a date in the edit control *Find Date* sets the cursor (little black arrow) on the first data set of this date. Now the user can choose the data set for the relevant time and confirms by clicking on the OK button. The chosen data set is applied automatically to the following dispersion simulation.

The reliable storage of meteorological measurement values serves two aims: first of all on the basis of the stored meteorological values, dispersion situations and concentration fields can be presented, in order to check the plausibility of complaints for past periods. Moreover, statistical analyses are possible, Predictions about occurrence frequencies and typical times of critical states can be received (the statistic module do not belong to the delivery of the standard version). Using those site referring statistics a much more precise prognosis of the odour impact in the surroundings of the plant will be possible in comparison with synoptical data from remote weather stations. Furthermore, important turbulence data are stored in terms of wind fluctuations values in the database. These are usually not available for performing dispersion calculations.

⊗ The standard edition of OdorSonic do not contain these measures

Clicking on the menu entry *Save graphic as jpg* stores the present graphic on the client window to the disk. The degree of compression quality of the jpg-file is fixed in the menu *Project Data / Model Parameters*.

The menu entry *Copy* serves for copying the content of the client window to the clipboard, which can be used afterwards for processing in other computer applications.

I - 3.3 The Project Data Menu

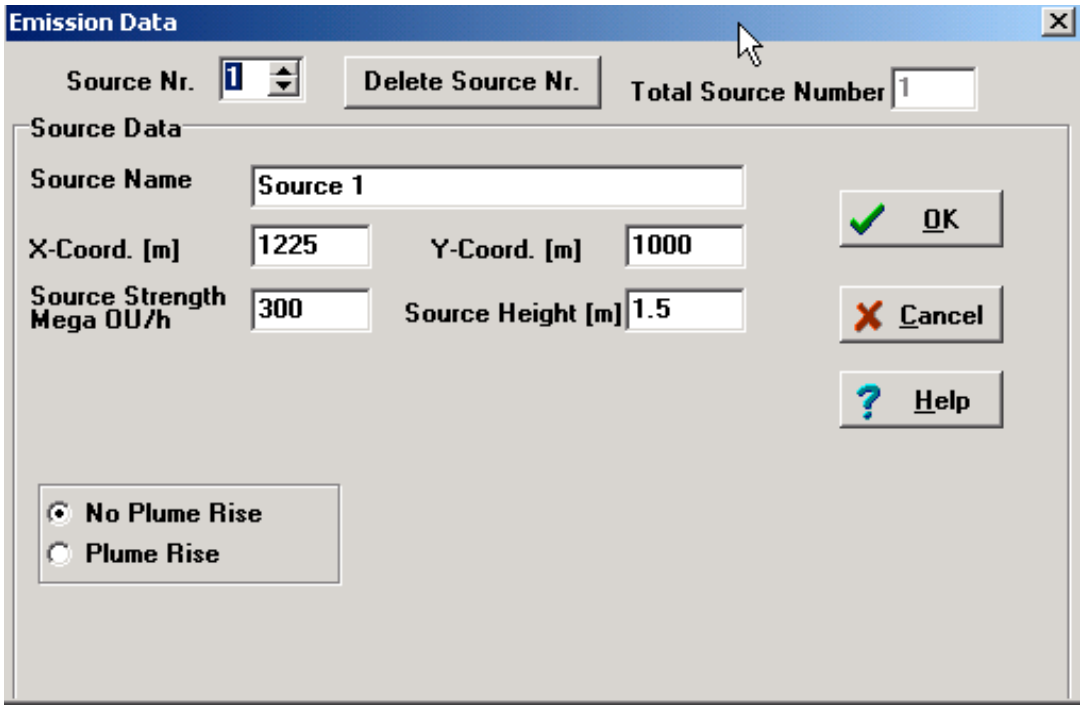
The Project Data pull down menu contains the following entries:

- *Emission Data*
- *Grid Data*
- *Meteorological Data*
- *Model Parameters*
- *Background Map*

In general, plausibility of the values is checked while the user is typing in data. If the entered data exceed or fall below some physical meaningful value they will be rejected with a hint. Accepted numerical values are automatically rounded to applicable digits in terms of model physics.

Basically, either the input of numerical data is expected (in this user's manual indicated with ☐) or a logical choice must be done (indicated with ◉). The program do accept decimal points as well as commas during the data input. Moreover the values can be entered in terms of scientific style, e.g. E3 or e-2.

Clicking on *Emission Data* in the menu Project Data opens the subsequent form in order to arrange emission data and related data will appear:



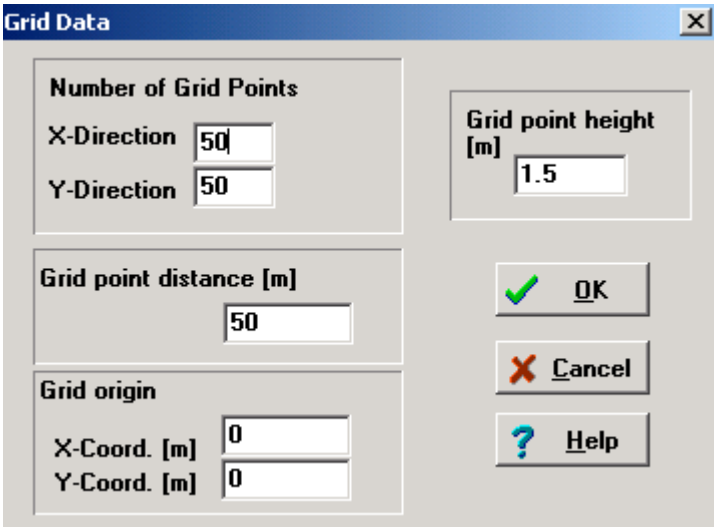
First of all the source number is entered either by clicking on the arrows at the spin editor or by inserting an integer. The maximum source number is 50 at present.

Then the user may define a designation for the source in question in the editor field ☐ *Source name*.

In the next row input of source co-ordinates is expected ☐ in meters (m). The numbers may be entered as relative co-ordinates defining a specific origin in the form *Grid Data*, or can be inserted in terms of absolute co-ordinates setting the origin to x = 0 and y = 0. Then the user have to determined the source strength ☐ in odour units per hour (OU/h) and the source height ☐ in meters (m).

Clicking on Plume Rise ◉ the program expects the data entry ☐ for the exhaust velocity in meters per second (m/s) and the stack diameter ☐ in meters (m).

The second entry in the menu Project Data is called *Grid Data*. Here the user can fix the numbers of grid points ☐ in x-direction and in y-direction, ranging between 3 and 50.



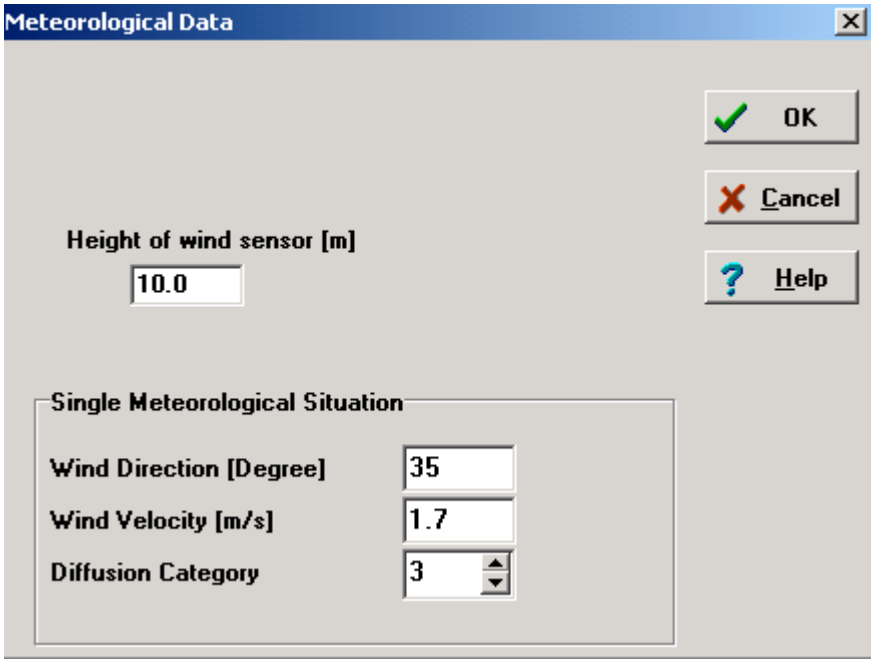
In the editor field Grid point distance ☐ the distance in meters (m) between two grid or receptor points is fixed. Together with the first two entries this defines the simulation domain, that, in general, is of rectangular shape and can be specified to a square format if x = y.

Next there are two edit fields to define the grid or co-ordinate origin. If the source co-ordinates should be determined in terms of relative co-ordinates, the user has to specify x- and y-co-ordinate of the left lower corner of the computing domain. Otherwise, the grid origin is set to x = 0 and y = 0 using absolute co-ordinates for the sources. In any case the user has

to check that the sources will be located in the simulation domain. The last edit field in this form is named *Grid point height* ☐, where the height in meters (m) of the grid or receptor points above the ground is fixed.

Normally, the grid data matches well with the dimensions of the background map and should not be changed. Make sure, that the scale of the background map is equal to the simulation domain; e.g. if the background map has width of 1000 m and height of 800 m the simulation domain must have the same measurements, the number of grid points in x-direction may be 40 and number of grid points in y-direction 32 combined with a grid point distance of 25 m.

The next entry in the Project Data Menu is named *Meteorological Data*. This form provides editor fields to fix some meteorological parameters:



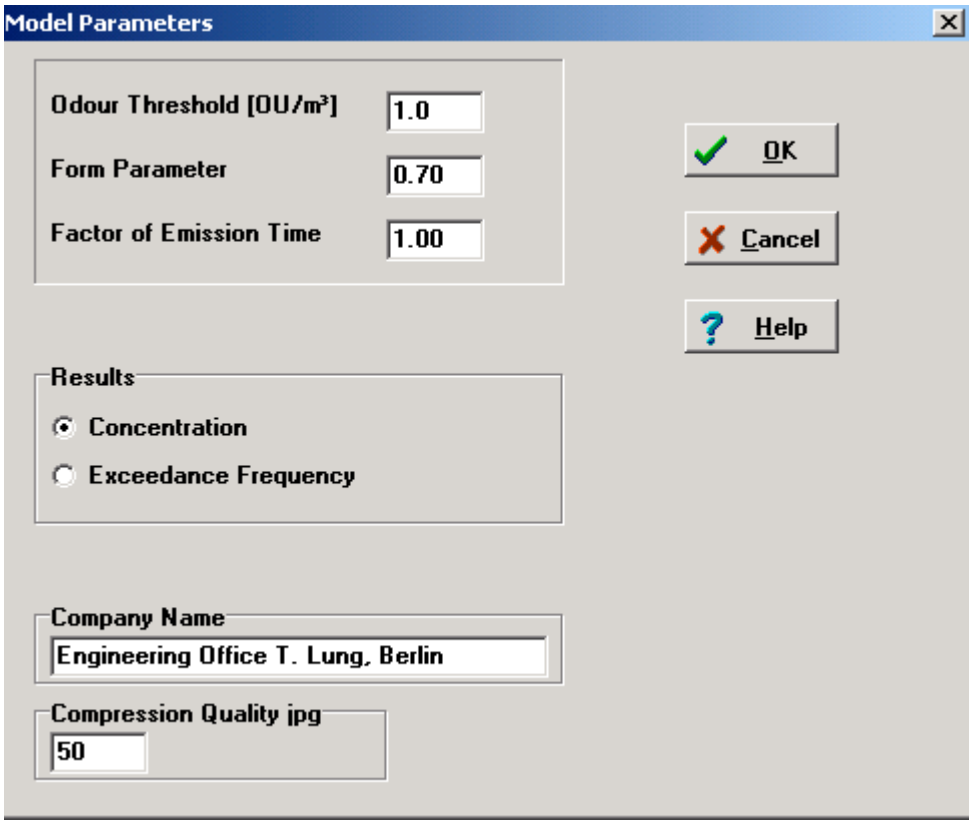
The first editor field ☐ fixes the height of the wind sensor in meters (m) above the ground. The following group box shows 3 fields in order to define a single meteorological situation to perform a dispersion simulation in offline modus. Wind direction ☐ in degrees, starting clockwise from 0 degree (north) to 360 degrees.

Next to it the user finds a field to fix the wind velocity ☐ in meters per second (m/s) followed by the spin editor field ☐ for the entry of a diffusion category ranging from 1 to 6.

For estimation of the diffusion category (DC) the user may apply the subsequent scheme:

DC NR.	AK from TA Luft (Germany)	DC according to Pasquill	Atmospheric stratification	Occurence
1	I	F	very stable	at night, cloudless, during weak winds
2	II	E	Stable	at night, slightly covered
3	III/1	D	Neutral	during the day, covered
4	III/2	C	slightly neutral	during the day, slightly covered
5	IV	B	Unstable	slight sunny day
6	V	A	very unstable	sunny day, cloudless

The next entry *Model Parameters* in the menu Project Date provides a form in order to fix the model parameters:



The default value in the edit field Odour Threshold ☐ is 1.0 odour units per cubic meter (OU/m^3) and should not be changed. In some cases it can be necessary to choose another odour threshold; the input field allows values in the range from 0.1 to 5.0 OU/m^3.

The form parameter ☐ is a measure for the concentration intensity. The default value is 0.7 and can be changed in the range from 0.1 to 2.0, where small values indicate low intensities. For reasons of simplicity the form parameter is set to a constant, although is varies with location.

The Factor of Emission Time ☐ describes fraction of the time while the sources are active. E.g. if all sources emit only in 60 % of the reference time, the factor is set to 0.6. Default value is 1.0 and should not be changed, since referring to a average time of 10 minutes sources are neither active (Factor = 1.0) or can switched off in the tool bar.

The simulation results can be optional presented ◉ either as concentration or as exceedance frequency.

In the edit field ☐ Company Name the user may input a designation for the company. Finally, it is possible to choose the Compression Quality ☐ (between 1 and 100) for exporting jpg-files, where small values indicates low image quality and small file seize.

I - 3.4 The View Menu

The following entries are listed in the View menu:

- *General View Project Data*
- *(Inspection Area)*
- *Numerical Values*
- *Isochromatics*
- *Isopleths*

The item *General View Project Data* provides a complete report of all project data. The input data are arranged as a report with two or more pages and can be printed. It is recommended to use the print function for documentation after typing in all project data.

The item *Inspection Area* is only enabled in the German version of OdorSonic because of the specific assessment method.

The function numerical values displays the simulation results as numerical values either of concentration or exceedance frequency in the client window.

Isochromatics is the default setting in the standard version of OdorSonic. This function displays the calculations results as Isochromatics, i.e. colour marked areas with the same numerical intervals.

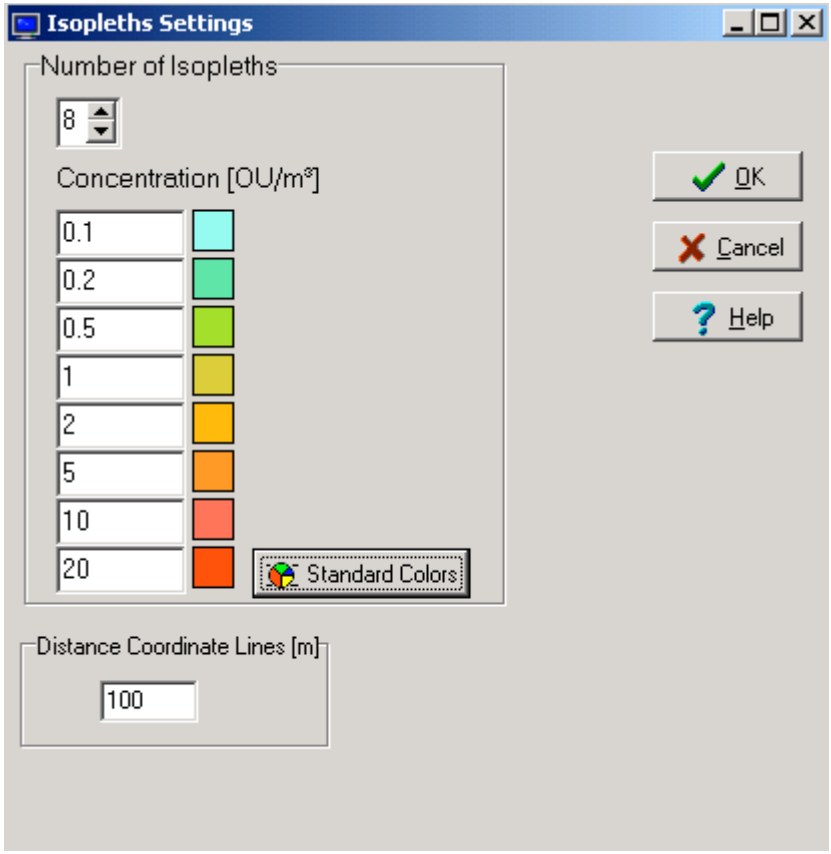
Finally, the results can also displayed as *Isopleths*, i.e. lines with the same concentration or exceedance frequency.

I - 3.5 The Settings Menu

Clicking on the first item *Show Sources* will display the locations of the sources on the background map. This way the user can easily check if the sources are located on the right place.

The item *Windrose Module* is disabled in the standard edition of OdorSonic. This windrose module belongs to a statistic package in an extended version.

The function *Values Isopleths* provides a dialog for graphics settings. Here the user can fix up to maximal 8 different values for isopleths or isochromatics



.A click on the button Standard Colors sets the predefined colours on the numerical values of the isopleths in case of changed colours. The colour of the isopleths or isochromatics can be changed by a click on the coloured square next to the edit fields. Hereby a Colour palette with a choice of 48 different colours appears.

Eventually, the user can fix a distance for the co-ordinate lines in meters (m).

I - 3.6 The Help Menu

The first item should provide a context sensitive online help for the program package OdorSonic (at present still disabled).

Windows Help calls the help system for the operation system Windows 2000 or XP.

About OdorSonic opens a form where information about the version number of the program as well as license designations can be found.

I – 3.7 Non Continuous Odour Sources

The first 10 project data sets entered in the *Emission data* form of the Project Data menu are displayed in the tool bar with their names. They can be either switched on or switched off depending on the emission state of the plant. In comparison with the switched off odour sources the activated sources will be applied in the dispersion simulation with their respective emission rates. This way the user can simulate emission reduced measures by switching off inactive odour sources.

All further odour sources listed in the project data set, i.e. 11^{th}, 12^{th}, 13^{th} source etc. will be treated as continuous sources. They can be fixed as permanent emitting sources, e.g. contaminated traffic areas.

I – 4 Additional Meteorological Sensors

Additional meteorological sensors are connected with the SonicDatenServer by means of a separate micro processor (see set up scheme of the OdorSonic system in paragraph I – 3). A stabilised industrial mains appliance provides power supply to the micro processor; at the same time the mains appliance provides the reference potential for the analogue inputs of the processor. Depending on the measurement task measuring objective and output signals the sensors are fitted and calibrated to the device in advance. For this purpose a program code is transmitted to the micro processor and saved in the EPROM.

Below follows an incomplete list of the most important meteorological sensors that can be connected with the OdorSonic system:

- Relative Humidity
- Precipitation (amount and intensity)
- Air pressure
- Net / Global radiation

Apart from the preceding listed sensor up to 20 more digital sensor can be connected with the micro processor. This way for example, information about opened gates or running conveying belts will be detected and stored in the database together with the respective working-periods. The storage of additional variables is achieved with the same time period as the meteorological variables, i.e. every 10 minutes. The database can be extended to those additional measures and the measurement values are listed in further columns.

I – 5 Database Access with Spreadsheet Analysis Programs

Basically, all data stored in the database of OdorSonic can be processed and statistically analysed by spreadsheet analysis programs. Even for long duration calculations of mean values, standard deviations, extreme values etc. of single parameters just as correlations between variables will be possible. Most spreadsheet analysis programs have efficient diagram modules so the imported data can be graphically displayed with a plenty of layout functions for prints or presentations.

Access to the OdorSonic database requires a proper installation of the PARADOX database driver within the applied program. Using Microsoft EXCEL the following steps are necessary for the set up:

1. Set up of the database driver: launch the application Dataacc on the MICROSOFT Office CD and install at least the PARADOX driver
2. Choose the entry *Extern Data* in the pull down menu Data of EXCEL:
   - New Query ...
   - Affirm the entry *New Data Source* in the form *Choose Data Source*
   - *Name of the new data source:* usa.db
   - *Driver:* (Microsoft) Paradox
   - *Connect*
   - *Choose directory* (where the database file usa.db is located)
   - *Options:* Sort Series: International
   - *Choose Query-Assistent Columns*: + usa.db >
   - *... Finish*

PART II Mathematical Modelling

II - 1 OdorSonic's Dispersion Model

II - 1.1 Fundamentals

It is the main task of dispersion simulation to calculate the concentration of airborne material as a function of time and space. Emission and meteorological data as well as the domain geometry of simulation are the most important input variables. Since this problem is highly complex some simplifying assumptions are made without neglecting the essential of physics.

The so-called Gaussian Plume Model presents the basis of the dispersion model in OdorSonic. It starts from a modified form of the equation of mass conservation that is the advection-diffusion equation:

$$\frac{\partial \bar{c}}{\partial t} + \bar{u} \cdot \frac{\partial \bar{c}}{\partial x} = \frac{\partial}{\partial y} \cdot \left(k_y \cdot \frac{\partial \bar{c}}{\partial y} \right) + \frac{\partial}{\partial z} \cdot \left(k_z \cdot \frac{\partial \bar{c}}{\partial z} \right) \qquad (1)$$

with $\bar{c}$: mean concentration, $\bar{u}$: mean wind velocity in direction of dispersion and
k_y, k_z : diffusion coefficients in the co-ordinate direction y and z

Assuming that

- the terrain surface is flat and there are no buoyancy forces
- wind direction does not change within the lowest 100 m of the atmosphere
- mean wind velocity is greater $\geq$ 1 m/s

the fundamental equation (1) can be simplified considerably.

Assuming further that

- there is no temporal change of the concentration
- meteorological parameters are constant

- a point source is emitting continuously at the position (0, 0, h) of the Cartesian co-ordinate system (see figure below),
- concentrations are Gaussian normal distributed in y- and z-direction
- there is a well-defined correlation between the diffusion coefficient of equation (1) and the dispersion parameters σ_y and σ_z,

the following equation is an analytical solution of the simplified equation of mass conservation:

$$\bar{c}(x,y,z) = \frac{Q}{2\pi \cdot \bar{u} \cdot \sigma_y \cdot \sigma_z} \cdot \exp\left\{-\frac{y^2}{2 \cdot \sigma_y{}^2}\right\} \cdot \left[\exp\left\{-\frac{(z-h)^2}{2 \cdot \sigma_z{}^2}\right\} + \exp\left\{-\frac{(z+h)^2}{2 \cdot \sigma_z{}^2}\right\}\right] \quad (2)$$

with

Q : emission rate of the source

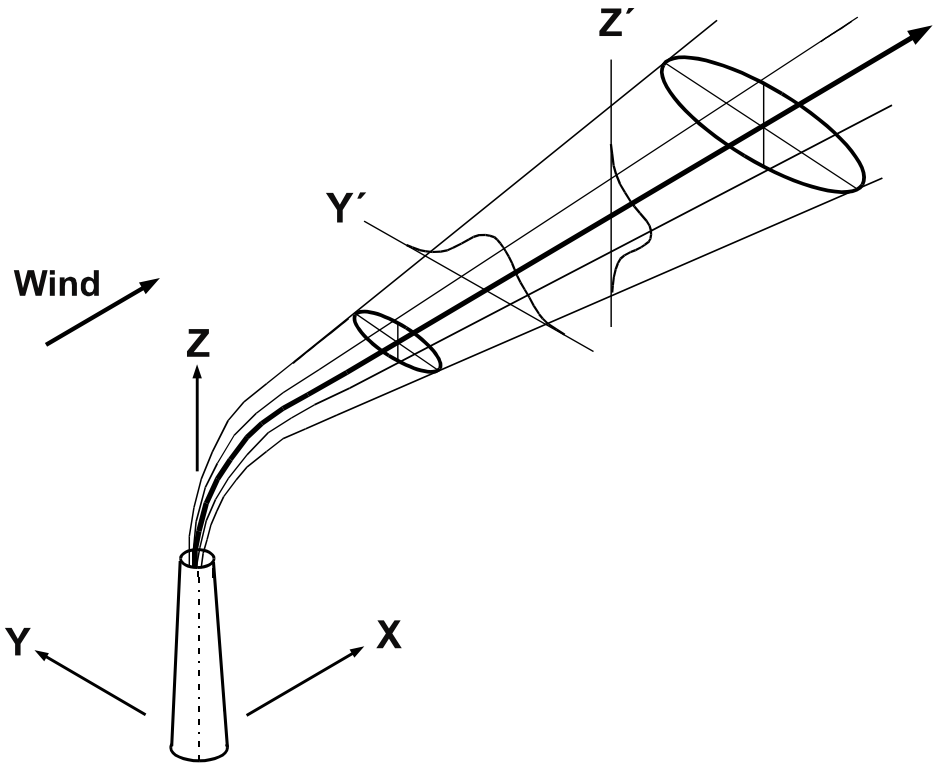
σ_y : standard deviation in y-direction (dispersion or sigma parameter)

σ_z : standard deviation in z-direction (dispersion or sigma parameter)

z : height of receptor above the ground

h : effective source height

The preceding formula, equation (2) presents a double Gaussian distribution, i.e. the mean concentration of a pollutant of odour source is normal distributed in y- and z-direction.



II - 1.2 Special Model Equations

There are a number of different schemes in order to specify the dispersion parameters in the Gaussian plume model; most often the TURNER and the PASQUILL schemes are applied. In Germany there has also been a parameterisation that refers to so-called KLUG/MANIER dispersion classes. However, those schemes suffer from the disadvantage of having only a small limited number of dispersion classes or categories. Consequently, regarding the mean concentration relatively large errors may occur for single meteorological dispersion situations. To reduce these errors a spectrum of turbulence states is applied for online dispersion simulations. In OdorSonic the calculation of dispersion parameters is achieved by the TAYLOR theorem using the following equations which are based on wind fluctuations:

$$\sigma_y(x) = \frac{\sigma_v \cdot t(x)}{\sqrt{1 + t(x)/(2 \cdot T_{Ly})}} \tag{3}$$

$$\sigma_z(x) = \frac{\sigma_w \cdot t(x)}{\sqrt{1 + t(x)/(2 \cdot T_{Lz})}} \tag{4}$$

where the diffusion time t(x) is equal to x / $\overline{u}$, x is the distance between the source and the receptor point and $\overline{u}$ denotes the mean wind velocity at the height of transport. σ_v is the standard deviation of the v-component of wind velocity, i.e. horizontal and rectangular to the mean wind direction. σ_w denotes the w-component of wind velocity (vertical component).

For reasons of simplicity the different components of the Lagrangian time scale are equaled to $T_L = T_{Ly} = T_{Lz}$. The time scale depends on σ_w i.e. a measure for the turbulence state of the atmosphere. Values of T_L range from approx. 3 s to 200 s.

II - 1.2.1 Wind Profile

The wind profile is modelled by means of a simple power law approach

$$\overline{u} = u_A \cdot \left(h/h_A\right)^m \tag{5}$$

where u_A is the wind velocity at the height of the anemometer, h_A is the height of the anemometer above the ground and m is a turbulence dependent exponent.

Apart from wind direction and velocity, the model kernel of OdorSonic uses information on the present state of atmospheric turbulence to calculate the concentration field. Here, the exponent m is a function of σ_w , more exactly, is parameterised by the standard deviation of the vertical wind component. At present, this simple wind profile is sufficient, since $\left(h/h_A\right)^m$ is a constant factor for a given atmospheric stratification. Looking at equation (2) this could be understood as a scaling factor for the emission rate Q, that has to be fitted anyway by the results of field inspections. If specific conditions require a more precise approach, a meteorological boundary layer model can be alternatively used.

II - 1.2.2 Plume Rise

Odour sources with forced exhaust ventilation e.g. the stack of a composting plant's biofilter, produce generally a plume rise Δh that must be added to the height of the stack H and yield the effective source height h :

$$h = H + \Delta h \tag{6}$$

The plume rise occurs due to 2 different physical effects: on the one hand side the mechanical exhaust impulse contributes to the plume rise; on the other hand a convective buoyancy force may rise the plume too, if there is a difference between the temperatures of the exhaust air and the ambient air. In OdorSonic a simple approach of the plume rise is implemented according to the German guideline VDI 3782 Sheet 3 :

$$\Delta h = \frac{0{,}35 \cdot v \cdot d + 84 \cdot \sqrt{M}}{\overline{u}} \tag{7}$$

with v: vertical exhaust velocity, d: diameter of the stack opening, $\overline{u}$: mean wind velocity (horizontal) and M: heat emission.

II - 1.3 The Fluctuation Model

The Gaussian plume model provides only the horizontal field of mean concentration that has no information on odour frequency. Those mean concentration values refer to an average time of about ½ hour. Mean concentration of odorants can be used for the evaluation of odour intensity, e.g. the isopleth of 1 OU/m^3. Note, that there could be definitely an odour perception at a fixed point even if the concentration is < 1 OU/m^3. In order to assess the odour impact situation more completely and to take the short-term changes of the concentration into account a statistical model is applied for the calculation of exceedance frequency.

In general, data sets of concentration are right-skewed. Therefore in OdorSonic the logarithmic normal distribution is adopted as the fluctuation model:

$$p(c) = \frac{1}{\sqrt{2\pi} \cdot c \cdot b} \cdot \exp\left\{ - \frac{\ln^2 (c/a)}{2 \cdot b^2} \right\} \tag{8}$$

where *a* is a scale parameter and *b* is a shape parameter.

The scale parameter *a* is tied to the mean odour concentration $\overline{C}$ whereas the shape parameter *b* depends exclusively on the intensity of fluctuation i_C :

$$b = \sqrt{\ln(i_C^2 + 1)} \tag{9}$$

with

$$i_C = \frac{\sigma_C}{\overline{C}} \tag{10}$$

where σ_C is the variance of concentration.

i_C and therefore b is not constant with respect to time and space. It depends on the meteorological conditions and flow obstacles (as e.g. buildings and vegetation). There has also been shown a dependence on the source size, the downwind distance and the position relative to the plume axis. Because of these complex functions the shape parameter is set to a constant in OdorSonic.

A value of *b* = 0,8 is likely to be a good choice, that corresponds to a intensity of fluctuation of $i_C^2 \cong 1$. Typically, the standard deviation of fluctuating pollutant concentration lies in the range of the mean concentration (see equation 10).

Finally, the exceedance frequency is received by integration of the density function equation (8)

$$H(c > c_S) = \int_{C_S}^{\infty} p(c)dc = erfc\left(\frac{b^2/2 + \ln C_S - \ln \overline{C}}{\sqrt{2} \cdot b}\right) \tag{11}$$

where C_S the threshold of odour (normally set to C_S = 1 OU/m^3) and erfc(...) is the complementary error function.

II - 2 On The Calibration of the OdorSonic System

Dispersion simulations suffer always from biases and uncertainties, that are mainly caused by different conditions of the varying locations. To a certain degree, these conditions (emission, orography, vegetation etc.) can be taken into account within a dispersion simulation by a comparison between the simulation results and the odour impacts. For this purpose a group of skilled panellists have to carry out odour field inspections during different meteorological situations and at different downwind positions. The dimensions and range of the plume is sensually measured so to say.

Plume inspections by panellists can be understand as olfactometrical measurements, however not at well-defined laboratory conditions, but under fluctuating full-scale conditions at full-scale. These meteorological (boundary) conditions are measured by the OdorSonic system during the plume inspection. So the following dispersion simulations use exactly the same wind and turbulence conditions that have been occuring during the inspection periods. Deviations between simulation and measurement results can be reduced by tuning the system. Mainly two variables are given for this tuning: the emission rate and the fluctuation intensity (shape parameter b

Whereas screening inspections by panellists do not measure the meteorological variables during the inspection periods; they only sample a Bernoulli variable (odour hour or no odour hour) over at least half a year without registration of the atmospheric wind and turbulence. This procedure suffers from relatively large statistical errors that can be quantified by the binomial distribution.

The measurement of wind direction, wind velocity and atmospheric turbulence provides a knowledge with respect to the evaluation of plume inspections that increases the prognosis confidence of the dispersion simulations by the OdorSonic system. Mathematically speaking, the plume inspection data could be regarded as 'conditioned probabilities'. That means: in comparison with screening inspections a very small number of inspection samples is required, since the statistical main unit is much smaller due to the 'fixed' meteorological conditions.

II - 2.1 Determination of Odour Frequency by Field Inspections

The extent and width of an odour plume can be 'measured' during defined dispersion situations. The determination of odour frequency by field or plume inspections provide important information on model fitting.

Commonly, the odour perceptions of the panellists were taken in terms of exceedance frequencies according to the integrating method of the German guideline VDI 3940. Herewith, the panellists stand cross-line to the mean wind direction, i.e. the center-line of the odour plume. The distance between the panellists depends on the number of employed persons, normally in the range from 10 m to 20 m. The panellists are equipped with pocket computers or stop watches to record the 'odour time'; their positions are taken by means of a Global Positioning System (GPS). The inspection periods last about 10 minutes and should be carried out during different meteorological conditions (preferably weak to mean wind velocities and stable to neutral atmospheric stratification) and at different down-wind locations. Wind direction, wind speed and turbulence are measured by the ultrasonic anemometer and stored in the database of the OdorSonic program system.

The next step is to perform odour dispersion simulation with exactly the same meteorological data as measured during the respective inspection period. Afterwards the results of the simulation are compared with measured data; in case of larger deviations between simulated and observed odour frequencies the emission rates and the shape parameter equation (9) are fitted to provide a better correspondence. This procedure forms the main constituent of the model calibration. The quality of model calibration can be documented through a diagram, where simulated odour frequencies are displayed versus observed values.